

What is claimed is:

1 1. Polarization interferometric apparatus, said
2 apparatus comprising interferometer means for receiving at
3 least two beams having orthogonal states of polarization
4 and providing first and second interferometer legs,
5 separating said two beams for travel along said first and
6 second interferometer legs, respectively, and generating
7 exit beams containing information about the respective
8 differences in the optical paths each beam experienced in
9 traveling said first and second interferometer legs, said
10 first and second interferometer legs having optical paths
11 structured and arranged such that at least one of them has
12 a variable physical length, the optical path length
13 difference between said first and second interferometer
14 legs varying in accordance with the difference between the
15 respective physical lengths of their optical paths and
16 wherein at least one of said first and second
17 interferometer legs comprises a polarization preserving
18 optical system.

1 2. The polarization interferometric apparatus of
2 claim 1 further including means for combining said exit
3 beams to produce mixed optical signals containing
4 information corresponding to the phase differences between
5 each of said exit beams from corresponding ones of said
6 predetermined optical paths of said first and second
7 interferometer legs.

1 3. The polarization interferometric apparatus of
2 claim 2 further including means for detecting said mixed

3 optical signals and generating electrical interference
4 signals containing information corresponding to the
5 difference in physical path lengths of said interferometer
6 legs and their relative rate of change.

1 4. The polarization interferometric apparatus of
2 claim 3 further including electronic means for analyzing
3 said electrical interference signals.

1 5. The polarization interferometric apparatus of
2 claim 1 wherein said polarization preserving optical
3 system comprises a plurality of reflecting surfaces
4 arranged such that a change in the direction of
5 propagation of an input beam, normal to both the input
6 beam and an output beam, causes a change in the direction
7 of propagation of the output beam in a direction opposite
8 to the direction of the change in the input beam, and a
9 change in the direction of propagation of the input beam,
10 normal to the input beam and in a plane orthogonal to a
11 normal to both the input beam and the output beam, causes
12 a rotation in the output beam in said plane that is the
13 same as a corresponding rotation of the input beam caused
14 by the change in the direction of propagation of the input
15 beam and wherein the plane of incidence at each of said
16 reflecting surfaces is either orthogonal or parallel to
17 the plane of polarization of an incident beam thereto.

1 6. The polarization interferometric apparatus of
2 claim 1 wherein said interferometer means comprises at
3 least one polarizing beam splitter for separating
4 orthogonally polarized beams for travel along

5 corresponding ones of said first and second interferometer
6 legs.

1 7. The polarization interferometric apparatus of
2 claim 1 wherein said interferometer means comprises at
3 least one plane mirror in one of said interferometer legs.

1 8. The polarization interferometric apparatus of
2 claim 7 wherein said interferometer means comprises at
3 least two polarization preserving optical systems, one for
4 reflecting beams corresponding to one interferometer leg
5 and another for reflecting beams corresponding to said
6 other interferometer leg.

1 9. The polarization interferometric apparatus of
2 claim 8 wherein said interferometer means further
3 comprises a polarization beam splitter for separating
4 orthogonally polarized beams and one of each of said at
5 least two polarization preserving optical systems is
6 arranged on opposite sides of said polarizing beam
7 splitter.

1 10. The polarization interferometric apparatus of
2 claim 1 wherein said interferometer means comprises a
3 plurality of optical elements, which include said
4 polarization preserving optical system, composed of glass
5 and arranged such that said separated beams traveling
6 along said first and second interferometer legs travel
7 through said optical elements composed of glass over
8 substantially equal optical path lengths to compensate for
9 thermal effects.

11. The polarization interferometric apparatus of claim 10 wherein said plurality of optical elements include a polarizing beam splitter having an entrance facet, an exit facet, a top facet, and a bottom facet, a first fixed plane mirror arranged above and substantially parallel to said top facet, a first quarter-wave plate located intermediate said first plane mirror and said top facet, a second movable plane mirror arranged substantially parallel to and opposite to said exit facet, a second quarter-wave plate fixedly located intermediate said second plane mirror and said exit facet, and wherein said polarization preserving optical system is arranged opposite to said bottom facet.

12. The polarization interferometric apparatus of claim 10 wherein said plurality of optical elements include a polarizing beam splitter having an entrance facet, an exit facet, a top facet, and a bottom facet, a first quarter-wave plate located immediately adjacent said exit facet, a first fixed plane mirror arranged opposite to and substantially parallel to said quarter-wave plate, a second movable plane mirror arranged substantially parallel to and adjacent said first fixed plane mirror, a pair of half-wave plates located opposite and substantially parallel to said entrance facet, and wherein said polarization preserving optical system is arranged opposite to said bottom facet, said first and second plane mirrors being moveable relative to one another such that opposing surfaces thereof may contact one another to form a substantially zero air gap between them.

1 13. The polarization interferometric apparatus of
2 claim 10 wherein said plurality of optical elements
3 include a polarizing beam splitter having an entrance
4 facet, an exit facet, a top facet, and a bottom facet, a
5 first fixed plane mirror arranged above and substantially
6 perpendicular to said top facet, a first quarter-wave
7 plate located intermediate said first plane mirror and
8 said top facet, a 45 degree mirror arranged between said
9 first quarter-wave plate and said first plane mirror, a
10 second movable plane mirror arranged substantially
11 parallel to and opposite to said exit facet, a second
12 quarter-wave plate fixedly located intermediate said
13 second plane mirror and said exit facet, and wherein said
14 polarization preserving optical system is arranged
15 opposite to said bottom facet, said first and second plane
16 mirrors being substantially parallel to one another.

1 14. The polarization interferometric apparatus of
2 claim 1 wherein said interferometer means is further
3 configured for receiving a second set of two beams and
4 providing a second set of first and second interferometer
5 legs, offset with respect to one another, separating said
6 two beams for travel along said second set of said first
7 and second interferometer legs, respectively, and
8 generating exit beams containing information about the
9 respective differences in the optical paths each beam
10 experienced in traveling said second set of said first and
11 second interferometer legs, said second set of said first
12 and second interferometer legs having optical paths
13 structured and arranged such that at least one of them has
14 a variable physical length, the optical path length

15 difference between said second set of said first and
16 second interferometer legs varying in accordance with the
17 difference between the respective physical lengths of
18 their optical paths and wherein at least one of said
19 second set of first and second interferometer legs
20 comprises a second polarization preserving optical system
21 to reduce polarization mixing between said second set of
22 two beams, whereby said polarization interferometric
23 apparatus is capable of measuring linear and angular
24 displacements.

1 15. The polarization interferometric apparatus of
2 claim 1 further including means for generating at least
3 two beams having orthogonal states of polarization.

1 16. The polarization interferometric apparatus of
2 claim 15 wherein said two beams have different
3 wavelengths.

1 17. The polarization interferometric apparatus of
2 claim 16 wherein said different wavelengths are
3 harmonically related.

1 18. The polarization interferometric apparatus of
2 claim 1 wherein said orthogonally polarized beams are
3 spatially separated.

1 19. The polarization interferometric apparatus of
2 claim 1 wherein said orthogonally polarized beams travel
3 along a coextensive path.

a

1 20. The polarization interferometric apparatus of
2 claim 5 wherein said polarization preserving
3 ~~retroreflector~~ ^{optical system} is fabricated of a plurality of prismatic
4 optical elements wherein said plurality of reflecting
5 surfaces comprise selected surfaces of said plurality of
6 prismatic optical elements.

1 21. The polarization interferometric apparatus of
2 claim 20 wherein at least one of said surfaces of said
3 plurality of prismatic optical elements operates by total
4 internal reflection.

1 22. The polarization interferometric apparatus of
2 claim 20 wherein said plurality of prismatic optical
3 elements comprise an integral assembly in which at least
4 one surface of each prismatic optical element contacts at
5 least one surface of another of said prismatic optical
6 elements. 23. The polarization interferometric apparatus
7 of claim 20 further including at least one polarizing beam
8 splitter.

1 24. The polarization interferometric apparatus of
2 claim 22 wherein said integral assembly further comprises
3 at least one polarizing beam splitter.

1 25. The polarization interferometric apparatus of
2 claim 20 wherein said prismatic elements of said optical
3 system comprise at least one prismatic element selected
4 from the group consisting of Porro, right, Dove, penta,
5 and "K" prisms.

1 26. The polarization interferometric apparatus of
2 claim 20 wherein said prismatic elements include a right,
3 a Porro and a penta prism.

1 27. The polarization interferometric apparatus of
2 claim 5 wherein at least one of said plurality of said
3 reflecting surfaces comprises a mirror.

1 28. The polarization interferometric apparatus of
2 claim 5 wherein at least one of said plurality of
3 reflecting surfaces has formed thereon a multilayer
4 polarizing beam splitter coating arrangement to enhance
5 the extinction ratio between orthogonally polarized beams
6 entering said polarization preserving ^{optical system} ~~retroreflector~~ from
7 upstream of it.

1 29. The polarization interferometric apparatus of
2 claim 20 wherein at least one of said plurality of
3 prismatic optical elements is formed of a birefringent
4 optical material.

1 30. The polarization interferometric apparatus of
2 claim 5 wherein said plurality of reflecting surfaces are
3 configured and arranged with respect to one another such
4 that beams enter and exit said polarization preserving
5 optical system substantially parallel and offset with
6 respect to one another.

1 31. The polarization interferometric apparatus of
2 claim 5 wherein said plurality of reflecting surfaces are
3 configured and arranged with respect to one another such

4 that beams enter and exit said polarization preserving
5 optical system substantially at right angles to one
6 another.

1 32. The polarization interferometric apparatus of
2 claim 31 wherein said plurality of reflecting surfaces are
3 further configured and arranged with respect to one
4 another such that beams that enter and exit said
5 polarization preserving optical system substantially at
6 right angles to one another also reside in planes that are
7 offset with respect to one another.

1 33. The polarization interferometric apparatus of
2 claim 30 wherein said plurality of reflecting surfaces are
3 further configured and arranged with respect to one
4 another such that an array of entering beams to said
5 polarization preserving optical system exit it as an array
6 of exiting beams substantially parallel to said array of
7 entering beams, said array of entering beams being offset
8 with respect to said array of exiting beams with both
9 residing in the same plane.

1 34. The polarization interferometric apparatus of
2 claim 30 wherein said plurality of reflecting surfaces are
3 further configured and arranged with respect to one
4 another such that an array of entering beams to said
5 polarization preserving optical system exit it as an array
6 of exiting beams substantially parallel to said array of
7 entering beams, said array of entering beams residing in
8 planes that are offset with respect to one another.

3 splitter arranged upstream of said entrance facet of said
4 right angle prism.

41. The polarization interferometric apparatus of claim 40 wherein one surface of said polarizing beam splitter and said entrance surface of said right angle prism are in optical contact with one another.

1 42. The polarization interferometric apparatus of
2 claim 1 further including in at least one of said
3 interferometer legs retardation elements for controlling
4 the state of polarization of orthogonally polarized beams
5 and reducing the effects of ghost reflections on exit
6 beams.

43. The polarization interferometric apparatus of claim 42 wherein said retardation elements comprise a pair of quarter wave plates oppositely tilted with respect to one another.

1 44. The polarization interferometric apparatus of
2 claim 1 wherein said interferometer means is further
3 structured and arranged such that the orthogonally
4 polarized beams make at least a double pass in traveling
5 along said interferometer legs.

1 45. The polarization interferometric apparatus of
2 claim 1 further including a microlithographic means
3 operatively associated with said interferometric apparatus
4 for fabricating integrated circuits on wafers, said
5 microlithographic means comprising:

6 at least one stage;
7 an illumination system for imaging spatially
8 patterned radiation onto the wafer; and
9 at least one positioning system for adjusting the
10 position of said at least one stage;
11 wherein said interferometric apparatus is adapted to
12 measure the position of said at least one stage.

1 46. The polarization interferometric apparatus of
2 claim 1 further including a microlithographic means
3 operatively associated with said interferometric apparatus
4 for use in fabricating integrated circuits on a wafer,
5 said microlithographic means comprising:
6 at least one stage for supporting a wafer;
7 an illumination system including a radiation source,
8 a mask, a positioning system, a lens assembly, and
9 predetermined portions of said interferometric apparatus,
10 said microlithographic means being operative such
11 that the source directs radiation through said mask to
12 produce spatially patterned radiation, said positioning
13 system adjusts the position of said mask relative to
14 radiation from said source, said lens assembly images said
15 spatially patterned radiation onto the wafer, and said
16 interferometric apparatus measures the position of said
17 mask relative to said radiation from said source.

1 47. The polarization interferometric apparatus of
2 claim 1 further including microlithographic apparatus
3 operatively associated with said interferometric apparatus
4 for fabricating integrated circuits comprising first and
5 second components, said first and second components being

6 moveable relative to one another, said first and second
7 components being connected with said first and second
8 measurement legs, moving in concert therewith, such that
9 said interferometric apparatus measures the position of
10 said first component relative to said second component.

1 48. The polarization interferometric apparatus of
2 claim 1 further including a beam writing system
3 operatively associated with said interferometric apparatus
4 for use in fabricating a lithography mask, said beam
5 writing system comprising:

6 a source for providing a write beam to pattern a
7 substrate;

8 at least one stage for supporting a substrate;

9 a beam directing assembly for delivering said write
10 beam to the substrate; and

11 a positioning system for positioning said at least
12 one stage and said beam directing assembly relative to one
13 another,

14 said interferometric apparatus being adapted to
15 measure the position of said at least one stage relative
16 to said beam directing assembly.

Sub
A2
1 49. Polarization interferometric apparatus, said
2 apparatus comprising interferometer means for receiving at
3 least two beams having orthogonal states of polarization
4 and providing first and second interferometer legs,
5 separating said two beams for travel along said first and
6 second interferometer legs, respectively, and generating
7 exit beams containing information about the respective
8 differences in the optical paths each beam experienced in

Sub
A2
concl'd

9 traveling said first and second interferometer legs, said
10 first and second interferometer legs having optical paths
11 structured and arranged such that at least one of them has
12 a variable physical length, the optical path length
13 difference between said first and second interferometer
14 legs varying in accordance with the difference between the
15 respective physical lengths of their optical paths, said
16 interferometer means further including a plurality of
17 opposing surfaces at least some of which are tilted with
18 respect to others to reduce the effects of ghost beams on
19 exit beams.

Sub
A3

1 50. The polarization interferometric apparatus of
2 claim 49 wherein at least one of said first and second
3 interferometer legs includes a polarization preserving
4 optical system.

1 51. The polarization interferometric apparatus of
2 claim 1 wherein said interferometer means further includes
3 dynamic means for maintaining the alignment of at least
4 one of said beams as it travels along a corresponding one
5 of said interferometer legs.

1 52. The polarization interferometric apparatus of
2 claim 51 wherein interferometer means comprises at least
3 one plane mirror for receiving one of said beams and said
4 dynamic means comprises a servo controlled mirror for
5 maintaining said beam substantially orthogonal to said
6 plane mirror.

1 53. The polarization interferometric apparatus of
2 claim 1 wherein said interferometer means is further
3 configured and arranged for receiving at least two
4 additional beams having orthogonal states of polarization
5 and providing two additional first and second
6 interferometer legs, separating said two additional beams
7 for travel along said two additional first and second
8 interferometer legs, respectively, and generating
9 additional exit beams containing information about the
10 respective differences in the optical paths each said
11 additional beam experienced in traveling said additional
12 first and second interferometer legs, said additional
13 first and second interferometer legs having optical paths
14 structured and arranged such that at least one of them has
15 a variable physical length, the optical path length
16 difference between said additional first and second
17 interferometer legs varying in accordance with the
18 difference between the respective physical lengths of
19 their optical paths and wherein at least one of said
20 additional first and second interferometer legs comprises
21 a polarization preserving optical system.

1 54. The polarization interferometric apparatus of
2 claim 53 wherein said interferometer means is configured
3 to simultaneously determine displacement and/or angle
4 along at least two axes.